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Thermal Performance and Flight Qualification of a Mini Loop Heat Pipe for Mars Rovers

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ABSTRACT

Rovers used in exploration of Mars have significant challenges for thermal control of electronics and instruments. Seasonal and daily temperature variations create conditions in which heat rejection and heat retention must be accommodated in the Rover thermal design. A mini Loop Heat Pipe (LHP) was designed for extending the operating time of the Solid State Power Amplifier (SSPA) used in the Rover Direct-to-Earth (DTE) communication system. The LHP, equipped with start-up and compensation chamber heaters, allows excess heat to be rejected during the warmest phase of the mission while allowing heat to be retained during the coldest phase of the mission.

This paper describes the thermal design requirements, the thermal performance characteristics and the flight qualification program of the mini-LHP for the twin 2003 Mars Rovers. The LHP was qualified to operate over a temperature range of –15C to +70C at the evaporator and –120C to +65C at the condenser. Ammonia was used as the working fluid in the LHP. The performance of the LHP was evaluated with a heat load ranging from 10 to 100 watts. The LHP demonstrated satisfactory performance during start-up with an attached thermal mass of 3 kg of aluminum and successful shut-down with a 1 watt compensation chamber heater.

The condenser was made from an aluminum panel (1 mm thick) bonded to a stainless steel condenser line, [1/16 inch (1.6 mm) O.D]. The condenser operated successfully through 100 freeze-thaw cycles without any physical damage or permanent deformation. The condenser panel was instrumented with strain gages before bonding to the condenser line. These were used to collect strain data and calculate the stress on the condenser induced during the bonding process and during thermal cycling. The stress values were then used to determine margins on plastic deformation and fatigue life.

The mini-LHP successfully passed the qualification program by meeting the design requirements for heat transport, thermal conductance, start-up, shut-down and condenser freezing with subsequent thawing.